The Effects of Life Span Development on Spatial Updating of Haptic Arrays

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Abstract: This research compared the accuracy for updating spatial images (3D representations of space in working memory) built up from learning object arrays through physical touch by participants ranging from 20 to 80 years of age. Participants were split into three age groups and learned four-target 'table-top' circular arrays. Participants then performed pointing judgments of relative direction (JRDs) and a re-creation task after physical or mental spatial updating. Pointing judgment results showed significant differences between age group, with the youngest age group having the best performance and oldest groups showing the worst. Re-creation task results revealed a similar pattern of significance with the youngest age group showing the best performance and least errors and the oldest group yielding the most errors. Initial results support the notion of a degradation of spatial image development and spatial updating performance with age.

Keywords: Spatial Image, Life Span Development, Haptics, Individual Differences, Spatial Cognition

1 Motivation

The effects of age and lifespan development create important issues for modern society. Among other mental and physiological changes, age leads to a decrease in the acuity of our sensory modalities (e.g., vision and audition). Information from these channels is critical for performing many activities of daily living; thus, age-related sensory loss can pose significant problems for the independence and quality of life for elders. Exploring individual differences (such as age and spatial abilities) observed between modalities on various tasks that test spatial learning and updating will provide valuable insight about life span development and spatial information processing. A deeper understanding of the cognitive changes associated with aging will also yield new adaptive methods for development of modern technologies; a future goal of this research. These new methods will aid the accuracy and safety of navigation for the aging demographic which represents the fastest growing segment of the U.S. population.

2 Background

Spatial representations of our surroundings are developed through sensory input from vision, audition, and touch, as well as linguistic mediation. Vision has been the center of the human spatial cognition model; however, several alternative theories have postulated a common representational format in memory for different input modalities of vision, audition, touch, and language. Examples include the spatial representation system [1] and the spatial image [2]. Several lines of evidence have provided empirical support for a theory of common spatial representations. For instance, comparable updating performance has been found between various input modalities, suggesting the development of functionally equivalent spatial images in memory [see 3 for review]. Age effects on cognitive processing are an important topic to explore given the rapid aging of our population, with some theories, such as the speed-processing theory [4], attributing cognitive decline to the inability for rapid completion of cognitive processes. The goal of this research is to compare the accuracy for updating spatial images in working memory built up from learning objects through physical touch by participants ranging from 20 to 80 years of age.

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3 Methodology

Thirty-six participants (19 female and 17 male) were recruited for this study, split equally between three age groups of 20-39 (M = 25.0, SD = 4.7), 40-59 (M = 50.8, SD = 5.8), and 60-79 (M= 70.3, SD = 4.6). The apparatus consisted of four 24 inch diameter Masonite circles containing four targets, one inch diameter magnets covered in either velvet, sandpaper, plastic, or rubber material (providing a unique texture for each), placed at varying locations per board. The study was run in five phases including a 1 minute blind-folded learning period, followed by egocentric pointing to each target, multiple JRD trials, re-exposure to the array, and concluding with a re-creation task (placing magnets on a blank 24 inch metal circle) after spatial updating. Spatial Updating was done as either real movement, where the participant physically walked around the table left or right 90 degrees, or by imagined movement, where the participant stayed at the learning orientation but imagined that they had moved left or right 90 degrees. This was done for each of the four target arrays with every subject completing the same tasks on the same arrays presented in a random order. Angle Error was calculated from the pointing trials and time and distance error were calculated from target placement after the re-creation task.

4 Initial Results

A one way ANOVA of absolute angle error in pointing judgments revealed the youngest age group to be the most accurate and the oldest the least, $F(2,33) = 23.93$, $p < .001$. Means in degrees for the age groups are as follows: 20-39 (M = 21.1, SD = 26.3), 40-59 (M = 26.1, SD = 32.3), and 60-79 (M = 40.7, SD = 44.8). A one way ANOVA for target placement time after updating showed the youngest group to take the most time during re-creation while the middle age group took the least, $F(2,33) = 9.36$, $p < .001$. Means in seconds for the three age groups are as follows: 20-39 (M = 77.6, SD = 21.2), 40-59 (M = 58.1, SD = 21.9), and 60-79 (M = 66.2, SD = 23.3). Finally, a one way ANOVA on distance errors for target re-creation after updating showed the youngest age group to be the most accurate and the oldest the least, $F(2,33) = 19.98$, $p < .001$. Means for the distance error in centimeters for the three age groups are as follows: 20-39 (M = 7.1, SD = 7.7), 40-59 (M = 8.6, SD = 7.7), and 60-79 (M = 12.2, SD = 9.6). No reliable differences were found between physical and imagined updating as a function of age.

5 Discussion

Congruent with our prediction for a loss in precision of the spatial image as a function of age, the current results show that spatial images built up from haptic learning can be accurately updated but that performance differs across the life span. These findings, along with further studies, will form the foundation of an understanding used to improve Gerontechnology. Future work will continue to look at input from multiple sensory modalities as a function of age in the context of spatial ability and mental representations of spatial images.

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